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Three related experimental studies analyzed rate and accuracy of test response under time-limit and no-time-limit conditions. Test instructions and multiple-choice vocabulary items were administered by computer. Student volunteers received monetary rewards under both testing conditions. In the first study college students were blocked into high- and low-ability groups on the basis of pretest scores. Results for both ability groups showed higher response rates under the time-limit conditions than under no-time-limit conditions. There were no significant differences between time-limit and no-time-limit. (Author)

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EFFECTS OF TIME LIMITS ON TEST-TAKING BEHAVIOR

T. W. Miller

and

David J. Weiss

U S DEPARTMENT OF HEALTH, EDUCATION & WELFARE
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Three related experimental studies analyzed rate and accuracy of test response under time-limit and no-time-limit conditions. Test instructions and multiple-choice vocabulary items were administered by computer. Student volunteers received monetary rewards under both testing conditions. In the first study college students were blocked into high- and low-ability groups on the basis of pretest scores. Results for both ability groups showed higher response rates under time-limit conditions than under no-time-limit conditions. There were no significant differences between time-limit and no-time-limit

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accuracy scores. Similar results were obtained in a second study in which each student received both time-limit and no-time-limit conditions. In a third study each testee received the same testing condition twice, and higher response rates were observed under the time-limit condition; response accuracy remained consistent across testing conditions. All three studies showed essentially zero correlations between response rate and response accuracy. Response latency data were also analyzed in the three studies. These data suggested the existence of different test-taking styles and strategies under time-limit and no-time-limit testing conditions. The results of these studies suggest that number-correct scores from time-limit tests are a complex function of response rate, response accuracy, test-taking style and test-taking strategy, and therefore are not likely to be as valid or useful as number-correct scores from no-time-limit-tests.

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Effects of Time Limits on Test-Taking Behavior

Rate and accuracy of response are important variables in the study of ability test performance. Response rate is reflected in several kinds of measurements, including average response latency, the time taken to complete a test, the number of item responses that are made in a fixed period of time, and the average number of item responses per unit of time. Accuracy of response refers to measurements such as the number of items answered correctly and the proportion of items answered correctly by a given individual. As the terms are used here, *rate* and *accuracy* refer to response characteristics; they are characteristics of test-taking behavior. These terms should not be confused with the terms *speed* and *power*, which refer to test characteristics.

The relationship between rate and accuracy of response has been studied actively since the turn of the century. Much of the research has compared test scores obtained under time-limit versus no-time-limit conditions. Previous reviews of the relevant literature have been presented by Highsmith (1925), McFarland (1928), Tryon and Jones (1933), Bennett (1941), Himmelweit (1946), and Nummenmaa (1960). An extensive bibliography has been provided by Morrison (1960).

Miller (1974) has identified three major viewpoints with regard to rate and accuracy in ability test performance: 1) rate and accuracy are indicative of the same underlying ability; 2) rate and accuracy represent separate abilities; and 3) rate and accuracy depend upon personality and motivational factors as well as upon ability. The first viewpoint was typified by the work of Spearman (1904, 1927) and a number of early researchers at the Harvard Psychological Laboratory (McFarland, 1930; Peak and Boring, 1926). The second viewpoint derives from the research of Baxter (1941), Davidson and Carroll (1945), and Horn and Bramble (1967). Thurstone (1937) set the stage for research motivated by the third viewpoint, dealing with time limits and test bias. Much of the psychometric research dealing with time-limit versus no-time-limit testing conditions has been guided by one or another of these viewpoints.

A distinction between rate and accuracy of response becomes particularly important when tests are administered under time-limit conditions. An individual's time-limit test score, or the number of items answered correctly within a time period, is a function of both rate and accuracy of response. If the testee maintains a constant level of accuracy but increases his/her rate, his/her time-limit test score will increase. If the testee maintains a constant rate of response but increases his/her accuracy, his/her time-limit test score will increase. Similarly, decreases in rate or accuracy will cause corresponding decreases in time-limit test scores. Unfortunately, many of the previous studies comparing time-limit and no-time-limit testing conditions have used the number of correctly answered items as the major dependent variable. A better understanding of test-taking behavior under time-limit versus no-time-limit conditions would be obtained by using separate measurements of rate and accuracy

of response.

Separating the effects of rate and accuracy in ability test performance has other advantages as well. Since different individuals can obtain the same time-limit test score through different combinations of rate and accuracy, time-limit test scores may be factorially complex. Because of their complexity, they may be more difficult to interpret and less useful in predicting external criteria. It is often argued that time-limit testing procedures penalize the slow but accurate responder. By obtaining separate rate and accuracy measurements, the slow but accurate responder can be identified and his test-taking behavior studied. Rate and accuracy scores could also be used as separate measurements of an individual's ability level.

By using computerized test administration it is possible to make accurate measurements of item response latencies. Such information might have diagnostic and predictive utility, especially in situations where individuals have different rates of response but similar levels of accuracy. Item response latencies can be utilized in the study of test-taking styles. Response rate or test-taking styles could also prove to be important moderator or predictor variables in prediction studies.

Within the context of the research on adaptive ability testing reported in this series, the present research illustrates an additional application of on-line computers in psychological measurement. Previous research into rate and accuracy in ability test performance was limited to paper-and-pencil test administration. The present research utilizes computerized test administration to make accurate measurements of item response latencies and response rates. The three studies reported below utilize separate measurements of rate and accuracy of performance. These measurements of rate and accuracy are studied under both time-limit and no-time-limit conditions of ability test administration.

General Methodology

Each of the three studies reported below was addressed to the same basic question: What are the differences in test-taking behavior under time-limit versus no-time-limit conditions? Test-taking behavior was operationalized by measurements of both rate and accuracy of response and by an intra-individual analysis of response latencies. Different experimental designs were used in each of the studies, but in many respects the studies employed the same general methodology.

Testees

The testees for the three studies were undergraduate student volunteers from the University of Minnesota. Prior to experimental

testing the students were informed that they would be taking a multiple-choice test of verbal ability and that they would receive a penny for every correct answer that was given. There were 72 students in Study 1, 30 in Study 2, and 30 in Study 3.

Ability Tests

The tests consisted of multiple-choice vocabulary items. A complete listing of these items is given in Miller (1974); McBride and Weiss (1974) describe the calibration of the item pool. Study 1 utilized an untimed pretest consisting of 100 items and an experimental test consisting of 250 items. Studies 2 and 3 utilized two experimental tests consisting of 175 items each.

The item order within the experimental tests was determined as follows. First, the test items were grouped according to difficulty level. The p-level, or the proportion of individuals in the norm group answering an item correctly, was used as the index of item difficulty. The tests were composed of blocks of items, and each block of items within a test contained one item chosen at random from each difficulty level. The order of items within blocks was randomized in order to avoid introducing any cyclical effects. This procedure of item arrangement insured that the average item difficulty of each block of items would be approximately the same throughout each of the tests. A more detailed description of this method for arranging test items is given by Miller (1974).

Administrative Conditions

Each of the three studies utilized a Control Data Corporation 3200 digital computer to provide on-line control of the experiment. Test instructions and experimental test items were presented on cathode-ray terminals (CRTs) equipped with a typewriter keyboard for the recording of responses. The system could be used to administer tests to as many as six subjects at a time. Complete items were written on the CRTs instantaneously. There was virtually no delay between an individual's answering one item and the presentation of the next item. Item response latencies were recorded in milliseconds, although these measurements were accurate only to a tenth of a second when testing more than one individual at a time. Each item response was examined for admissibility, and skipping items was not allowed.

Each of the three studies employed time-limit and no-time-limit conditions, but the assignment of testees to experimental conditions varied from one study to the next. The nature of the testing conditions was described to the students in a series of instructional frames presented by the computer (see Miller, 1974, pp. 233-256). To insure that each testee was aware of the testing conditions, he/she was required to respond correctly to a series of computer-administered multiple-choice questions about the test instructions. Under a time-limit condition each item was presented with the item number in the upper

right-hand corner of the screen and with the time remaining (in minutes and seconds) at the bottom of the screen. Under a no-time-limit condition each item was presented with the item number alone.

Dependent Variables

Rate and accuracy of response constituted the primary dependent variables of interest. An individual's response rate was defined as the average number of item responses per minute. An individual's accuracy of response was defined as the proportion of items answered correctly out of those attempted. These two dependent variables were analyzed in separate analyses of variance, using experimental designs which varied across studies.

Item response time or item response latency is the length of time between the presentation of the test item and the testee's response to that item. Response latency is determined by three components: 1) The time it takes to read the item; 2) the time it takes to arrive at a solution to the item; and 3) the time it takes to record one's solution to the item. These three components--reading time, solution time, and recording time--will vary between individuals and between items.

By using multiple-choice items of similar length, inter-item differences associated with reading time can be reduced. Consequently, each item used in these studies consisted of a single stimulus word and five one-word alternatives. The task in responding to each item was the same: the testee was instructed to find the alternative closest in meaning to the stimulus word. By using items with a similar format and by administering items by computer, inter-item differences associated with recording time were reduced. Thus, by standardizing conditions relating to reading time and recording time, the major influence on a testee's rate of response was solution time.

Study 1

This study was designed to investigate individual differences in test-taking behavior under time-limit and no-time-limit conditions. The study employed a randomized block design with testees blocked into high- and low-ability groups according to their performance on a pretest. Such a design permits analysis of the extent to which high- and low-ability groups perform differently under time-limit and no-time-limit testing conditions.

Method

Procedure. In this study students first were administered a pretest consisting of 100 multiple-choice vocabulary items. This test was used to block the testees into two ability groups. Testees scoring above the median on the prestest were assigned to the *high-ability group*, and those scoring below the median on the pretest were assigned to the

low ability group. Testees from each ability group then were assigned randomly to one of the administrative conditions.

Under the time-limit condition testees were told that there was a 25-minute time limit and that the test contained 250 items. They were told that they would have to answer an average of 10 items per minute in order to finish the test. Under the no-time-limit condition the testees were told that there was no time limit and that the test contained 250 items. Students in both groups were told they would receive one cent for each item answered correctly.

Data analyses. The observations for rate and accuracy of response were analyzed in separate analyses of variance using 2 x 2 factorial designs. The first factor was the testing condition, time-limit versus no-time-limit. The second factor was ability level, high-ability group versus low-ability group. Pearson product-moment correlations were computed between selected pairs of the following variables: testing condition (0=time-limit, 1=no-time-limit), pretest score, response rate, and response accuracy.

The relationship between item difficulty (p-value) and mean item response latency was studied for each of the four cells in the design. For each of the 250 items the item p-value was obtained from the calibration study data (McBride & Weiss, 1974), and the mean item response latency was obtained by averaging the response latencies of all testees who attempted the item.

In addition to these analyses, a test response record was obtained for each individual in the study. This response record was a time-series plot of the number of responses per minute during each minute of the testing session.

Results

Response rate. Table 1 shows the means and standard deviations for response rate (number of responses per minute) in the four experimental groups. Also shown are the results of the analysis of variance using testing condition and ability level as the independent variables and response rate as the dependent variable. The mean response rate under the time-limit condition (8.56) was significantly higher ($p<.001$) than the mean response rate under the no-time-limit condition (5.77). The mean response rate for the high-ability group (7.61) was higher ($p<.10$) than the mean response rate for the low-ability group (6.73). There was no significant interaction between testing conditions and ability levels. The point-biserial correlation describing the degree of relationship between testing conditions and response rate was -.59.

Response accuracy. Table 2 shows the means and standard deviations for response accuracy in the four experimental groups. Also shown are the results of the analysis of variance for response accuracy. The

difference between mean response accuracies under time-limit versus no-time-limit conditions was not statistically significant. The mean

Table 1
Means, Standard Deviations and Analysis of Variance for the Number of Responses per Minute

Testing Condition and Ability Level	*N*	Mean	S.D.
Time-Limit Condition			
Total group	36	8.56	2.20
High-ability	18	9.00	1.68
Low-ability	18	8.12	2.59
No-Time-Limit Condition			
Total group	36	5.77	1.61
High-ability	18	6.21	1.30
Low-ability	18	5.33	1.80
Ability Group (Conditions Combined)			
High-ability	36	7.61	2.05
Low-ability	36	6.73	2.63

Analysis of Variance

Source of Variation	df	MS	*F*	*p*
Testing Condition	1	140.11	38.75	<.001
Ability Level	1	13.87	3.84	.051
Testing Condition *x* ability level	1	.00	.00	.995
Error	68	3.62		

accuracy score for the high-ability group (.60) was significantly higher ($p<.001$) than the mean accuracy score for the low-ability group (.36). This result was expected, however, since scores on a vocabulary pretest were used to block individuals into ability levels. The correlation between pretest scores and accuracy scores was .95. There was no significant interaction between testing conditions and ability levels in determining response accuracy. The correlation between response rate and response accuracy was .17 for individuals under a time-limit condition and .18 for individuals under a no-time-limit condition. Neither of these correlations was significantly different from zero.

Item response latencies. Figure 1a shows the bivariate distribution of item difficulties (p-values) and mean item response latencies (in seconds) for the high-ability group under the time-limit condition. The regression line for predicting mean latencies from item difficulties is plotted on this figure. For this group the correlation between item difficulty and mean item response latency was -.36 ($p<.01$). Figure 1b shows the bivariate distribution of item difficulties (p-values) and mean item response latencies (in seconds) for the high-ability group under the

no-time-limit condition, and the regression line for predicting mean latencies from item difficulties.

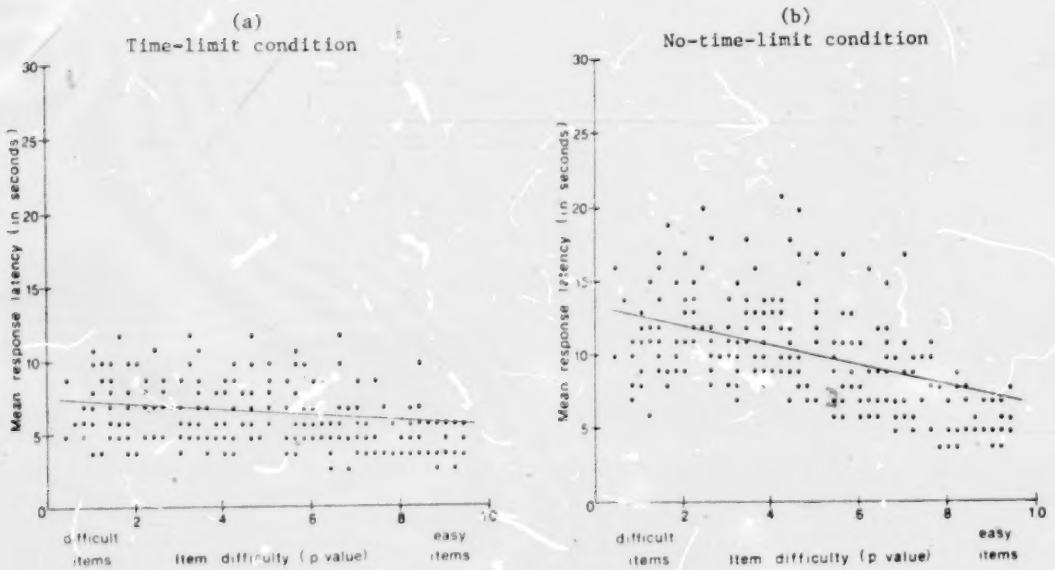
Table 2
Means, Standard Devisions and Analysis of Variance for the Proportion of Items Answered Correctly

Testing Condition and Ability Level	*N*	Mean	S.D.
Time-Limit Condition			
Total group	36	.47	.16
High-ability	18	.59	.14
Low ability	18	.36	.06
No-Time-Limit Condition			
Total group	36	.48	.16
High ability	18	.61	.10
Low-ability	18	.35	.07
Ability Group (Conditions Combined)			
High-ability	36	.60	.12
Low-ability	36	.36	.07

Analysis of Variance

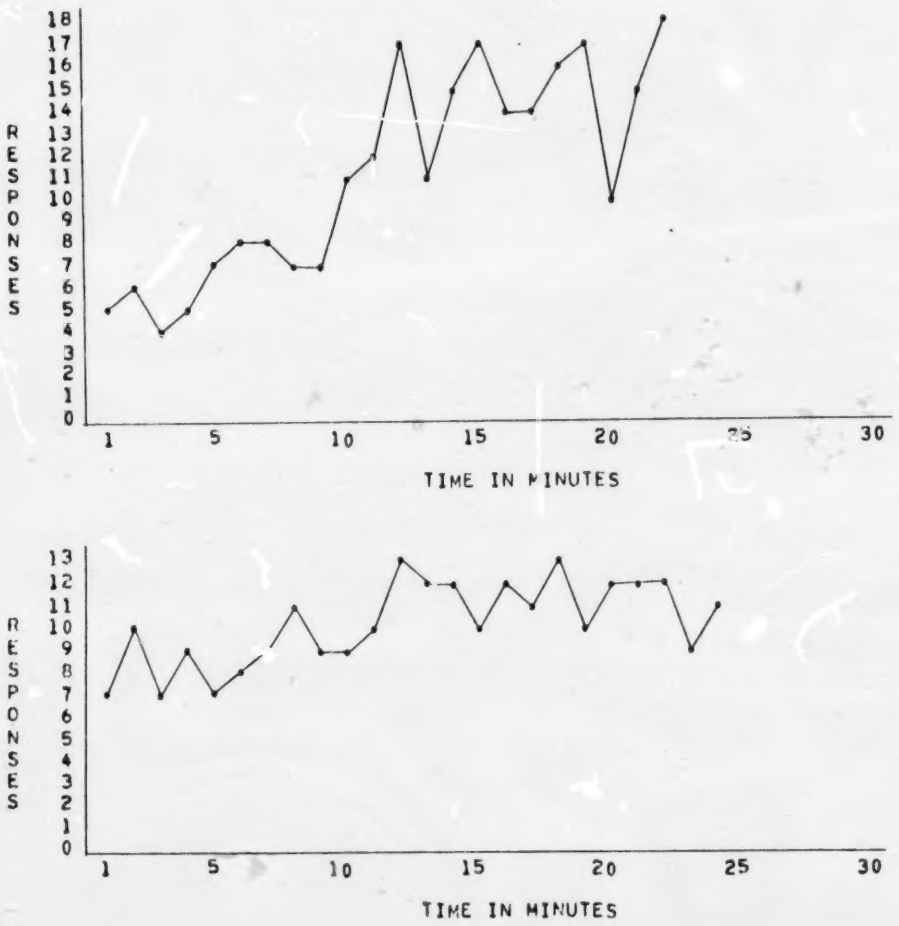
Source of Variation	df	MS	*F*	*p*
Testing Condition	1	.0033	.36	.555
Ability Level	1	1.1225	122.69	<.001
Testing Condition *x* ability level	1	.0070	.77	.611
Error	68	.0091		

Figure 1
Mean Response Latency as a Function of Item Difficulty for the High-Ability Group



For this group the correlation between item difficulty and mean item response latency was -.56 ($p<.01$). Both correlations were negative: longer response latencies were associated with the more difficult items (items with lower p-values). The difference in the magnitude of the correlations, which was statistically significant ($p<.05$), reflects the fact that testees spend proportionately less time in responding to the more difficult items under a time-limit condition than under a no-time-limit condition. A similar pattern of results was obtained for the low-ability group (see Miller, 1974, pp. 68-71).

Figure 2
Sample Response Records Resulting from
Time-Limit Administration



Test response records. The test response records for all of the individuals in this study are shown in Miller (1974); only four are presented here for illustrative purposes. Figure 2 shows sample test

response records for two testees who received the time-limit condition. Both testees whose response records are shown in Figure 2 completed all 250 items in the test within the time limit. Both testees received approximately the same number-correct score (104 for the upper response record and 107 for the lower), but their "styles" of test-taking behavior were quite different. The upper response record is typical of test-taking behavior under time-limit conditions. Most testees show a generally increasing response rate under these conditions, implying an adaptation effect or a motivational effect due to the time limit. However, as the lower part of Figure 2 shows, some testees obtained identical scores even though they worked at a consistent speed, without evidence of adaptation or motivational effects.

Figure 3
Sample Response Records Resulting from
No-Time-Limit Administration

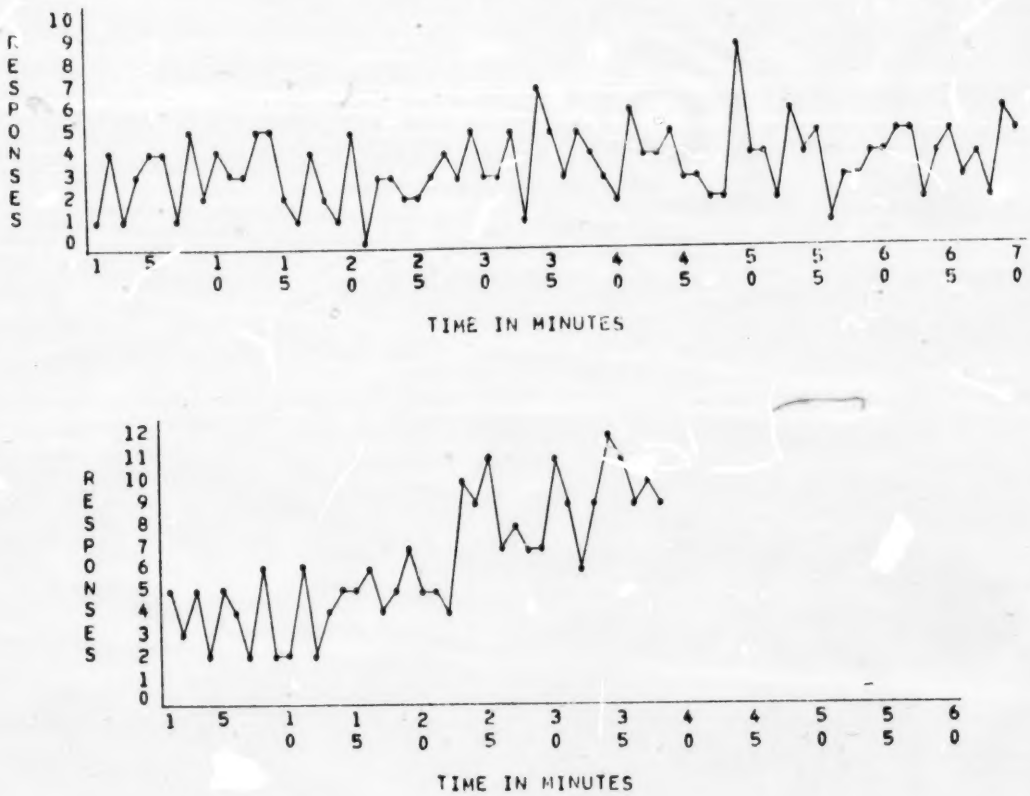


Figure 3 shows two sample response records under the no-time-limit testing condition. Both testees obtained approximately the same number-correct score (143 for the upper response record and 150 for the

lower). The upper response record is characteristic of response rate behavior under no-time-limit conditions. This testee answered a relatively constant number of items per minute throughout the test and took 70 minutes to complete the test. On the other hand, the test response record shown in the lower part of Figure 3 shows the characteristic adaptation or motivational pattern of the time-limit records, even though the test was administered under no-time-limit conditions.

Some of the response records show even more unusual patterns of response rates (see Miller, 1974, pp. 167-202). Thus, there is a wide range of individual differences in response rate patterns both between and within time-limit and no-time-limit testing conditions.

Conclusions. The results of this experimental study indicated that higher response rates are to be expected under time-limit conditions. There were no significant differences between response accuracies for time-limit versus no-time-limit conditions. The lack of a significant interaction between testing conditions and ability levels for either response rate or response accuracy indicates that testees from different ability levels show similar patterns of response in adapting to time-limit and no-time-limit conditions. By examining response latency data as a function of item difficulties under the two administration conditions, one can see what these response patterns entail. There was some evidence in these data that under a time-limit condition subjects spend proportionately less time in responding to the more difficult items than they do under a no-time-limit condition. Students maintain their level of accuracy under time-limit conditions although they increase their response rate. They do this by spending less time on the more difficult items than they do under no-time-limit conditions. The individual response records showed wide individual differences in behavior, implying different test-taking "styles". These different styles, if reliable within individuals, could be important moderator variables whose use might improve predictive validities based on ability test scores.

Study 2

This study was designed to investigate intra-individual variability in rate and accuracy of response. Study 1 showed different patterns of test-taking behavior between time-limit and no-time-limit conditions using a between-subjects design. This study used a within-subjects design.

Method

Procedure. Each student received two 175-item tests in succession, with one test administered under a time-limit condition and the other under a no-time-limit condition. Each testee was randomly assigned to one order of administrative conditions. The design was counterbalanced: 15 testees received the time-limit condition first, and 15 received the

no-time-limit condition first. Under the time-limit condition, testees were told that the test contained more than 150 items and that there was a 15-minute time limit. They were told that they would have to answer more than 10 items per minute in order to finish the test. Under the no-time-limit condition, testees were told that there was no time limit, but they were not told the number of items in the test. The testing sessions were terminated at the end of 15 minutes regardless of the testing condition. Again, each testee was paid one cent for each correct answer.

Data analyses. Repeated measurements analyses of variance were employed. Testing condition represented a within-subjects factor with two levels: time-limit condition versus no-time-limit condition. The order of testing conditions represented a between-subjects factor with two levels: time-limit condition first versus no-time-limit condition first. Pearson product-moment correlations were computed between selected pairs of the following variables: time-limit response rate, time-limit response accuracy, no-time-limit response rate, and no-time-limit response accuracy. The mean response latency for correctly answered items was compared to the mean response latency for incorrectly answered items. These mean latencies were examined for both time-limit and no-time-limit conditions.

Table 3
Means, Standard Deviations and Analysis of Variance for Number of Responses per Minute

Order and Type of Testing Condition	Mean	S.D.
Time-Limit Condition First (N=15)		
Both conditions combined	7.80	2.78
Time-limit	8.22	2.54
No-time-limit	7.38	2.95
No-Time-Limit Condition First (N=15)		
Both conditions combined	7.05	2.92
Time-limit	9.20	2.23
No-time-limit	4.89	1.66
Testing Condition (Orders Combined)		
Time-limit condition	8.71	2.44
No-time-limit condition	6.14	2.70

Analysis of Variance

Source of Variation	df	MS	F	p
Between Subjects				
Order of testing conditions	1	8.48	.79	.615
Subjects within groups	28	10.72		
Within Subjects				
Testing condition	1	99.85	138.86	.001
Order x testing condition	1	45.31	63.01	.001
Testing condition x subjects, within groups	28	.72		

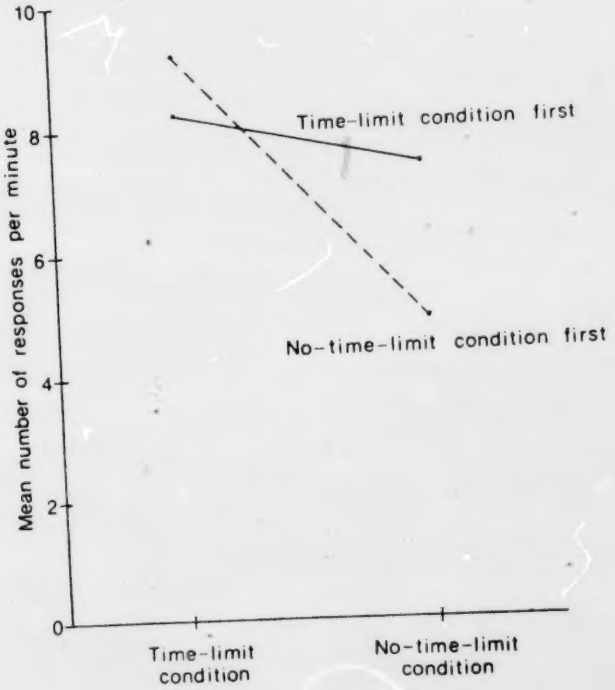
Results

Response rate. Table 3 shows the group means and standard deviations

for response rate under the time-limit and no-time-limit conditions. Also shown are the results of the repeated measurements analysis of variance. Regardless of the order of testing conditions within subjects, the mean response rate under the time-limit condition was higher than the mean response rate under the no-time-limit condition ($p<.001$).

The order of administration of testing conditions did not have a significant effect upon response rate by itself, but the interaction between the orders of administration and the testing conditions was significant ($p<.001$). Figure 4 shows the pattern of this interaction. When the no-time-limit condition was first, imposition of time limits led to a large increase in mean number of responses per minute. When the time-limit condition was administered first, there was virtually no decrease in response rate under the no-time-limit condition. For the testees receiving the time-limit condition first, the correlation between time-limit and no-time-limit response rates was .90. For those receiving the no-time-limit condition first, the correlation between time-limit and no-time-limit response rates was .88.

Figure 4
Group Means for the Number of Responses per Minute, Testing Condition and Order of Administration



Response accuracy. Table 4 shows the group means and standard deviations for response accuracy under the time-limit and no-time-limit conditions. Also shown are the results of the repeated measurements analysis

of variance. There were no significant main effects or interactions. For the testees receiving the time-limit condition first, the correlation between time-limit and no-time-limit response accuracies was .98. For those receiving the no-time-limit condition first, the correlation between time-limit and no-time-limit response accuracies was .86. Combining the data from both orders of administration, time-limit response rates correlated .08 with time-limit response accuracies, and no-time-limit response rates correlated .31 with no-time-limit response accuracies. While the correlation of .08 under time-limit conditions was not significantly different from zero, the correlation of .31 under no-time-limit conditions was significant at the .05 level. Thus, under no-time-limit conditions there was a tendency for higher scoring testees to answer test items more quickly.

Table 4
Means, Standard Deviations and Analysis of Variance for Proportion of Items Answered Correctly

Order and Type of Testing Condition	Mean	S.D.
Time-Limit Condition First (N=15)		
Both conditions combined	.54	.17
Time-limit	.54	.16
No-time-limit	.54	.17
No-Time-Limit Condition First (N=15)		
Both conditions combined	.46	.14
Time-limit	.46	.15
No-time-limit	.45	.13
Testing Condition (Orders Combined)		
Time-limit condition	.50	.16
No-time-limit condition	.50	.16

Analysis of Variance

Source of Variation	df	MS	F	p
Between Subjects				
Order of testing conditions	1	.1118	2.53	.120
Subjects within groups	28	.0443		
Within Subjects				
Testing condition	1	.0007	.41	.539
Order x testing condition	1	.0009	.49	.504
Testing condition x subjects, within groups	28	.0018		

Item response latencies. Table 5 shows the group means and standard deviations separately for the average response latency for correctly answered items and for incorrectly answered items under the time-limit and no-time-limit conditions. These mean latencies are plotted in Figure 5.

Regardless of the order of administration of testing conditions, mean latencies for correct responses were shorter under the time-limit condition than under the no-time-limit condition. Mean latencies for

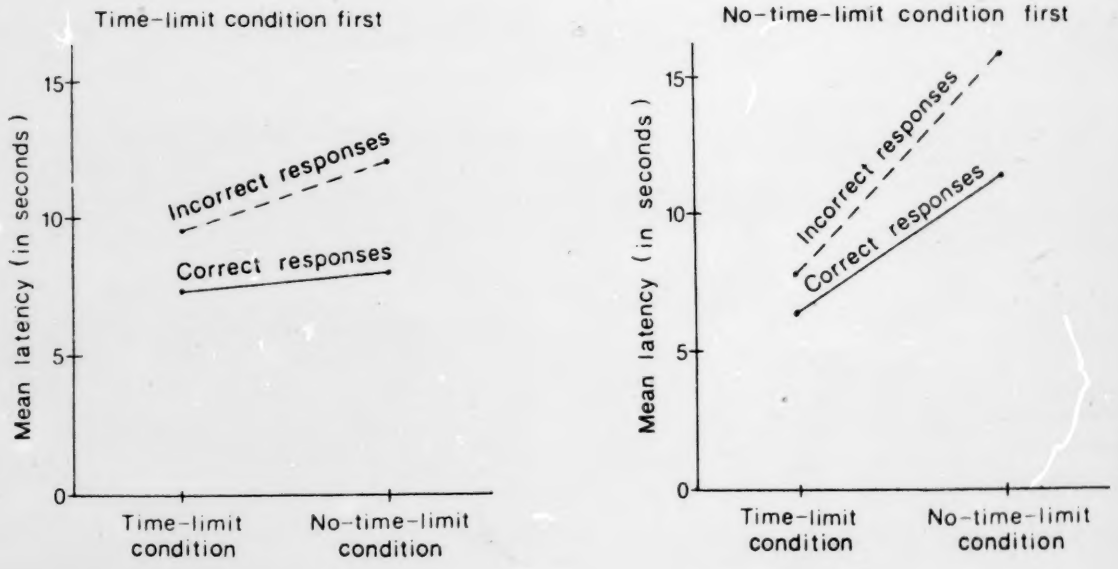
incorrect responses also were shorter under the time-limit condition than under the no-time-limit condition. In general, the mean latencies for correct

Table 5
Means and Standard Deviations for Average Latency of Correct and Incorrect Responses in Seconds

	Correct Responses		Incorrect Responses	
Order and Testing Condition	Mean	S.D.	Mean	S.D.
Time-Limit Condition First (N=15)				
Both conditions combined	7.67	3.18	10.75	4.78
Time-limit	7.25	2.95	9.59	3.19
No-time-limit	8.09	3.34	11.90	5.73
No-Time-Limit Condition First (N=15)				
Both conditions combined	8.80	3.66	11.80	5.10
Time-limit	6.25	1.51	7.76	2.62
No-time-limit	11.34	3.39	15.83	6.10
Testing Condition (Orders Combined)				
Time-limit condition	6.75	2.40	8.68	3.06
No-time limit condition	9.72	3.74	13.87	6.24

responses were shorter than the mean latencies for incorrect responses. It is interesting to note, however, that the differences in mean latencies between correct and incorrect responses were greater under the no-time-limit condition. Under a time-limit condition subjects spent proportionately less time in

Figure 5
Mean Latencies for Correct and Incorrect Responses Plotted for the Two Testing Conditions and Orders of Administration



responding to items which they answered incorrectly.

Conclusions. Generally speaking, the results of Study 2 were in agreement with the results of Study 1, although the design of the two studies differed. Higher response rates were observed in this study under time-limit conditions, and the highest response rates were observed when the time-limit condition followed the no-time-limit condition. As in Study 1, mean response accuracy was not affected by the imposition of time limits, but amount of time spent by testees on items answered correctly or incorrectly differed under the two administrative conditions. The fact that response rate and accuracy are different variables was illustrated by the near zero correlation between the two variables under time-limit conditions and by a low positive correlation under no-time-limit conditions.

Study 3

This study was similar to Study 2 in that it employed a within-subjects design; it examined intra-individual variability. It was uniquely designed to investigate learning or practice effects that could result when an individual moves from one time-limit testing session to the next or from one no-time-limit testing session to another. Such learning effects might include different test-taking strategies.

Method

Procedure. The test materials, instructions, and incentives were the same as those used in Study 2. In this study, however, each testee received the same testing condition (i.e., time-limit or no-time-limit) twice. There were 15 testees in each of the two experimental groups.

Data analyses. Repeated measurements analyses of variance were employed. Testing condition represented a between-subjects factor with two levels: time-limit condition versus no-time-limit condition. Testing session represented a within-subjects factor with two levels: Session 1 versus Session 2. Dependent variables were response rate and response accuracy. Pearson product-moment correlations were computed between selected pairs of the following variables: Session 1 response rate, Session 1 response accuracy, Session 2 response rate, and Session 2 response accuracy.

To examine possible learning or practice effects, the variability of item response latencies was examined across the testing sessions. The standard deviations (biased) of a subject's item response latencies were computed for the first and second testing sessions. These standard deviations were treated as dependent variables in a repeated measurements analysis of variance of the same type as those used for response rate and response accuracy.

Results

Response rate. Table 6 shows the group means and standard deviations for response rate under the time-limit and no-time-limit conditions. Also

shown are the results of the repeated measurements analysis of variance. The mean response rate under the time-limit condition (8.93) was significantly higher ($p<.001$) than the mean response rate under the no-time-limit condition (6.60). The mean response rate during the second testing session (8.25) was significantly higher ($p<.001$) than the mean response rate during the first testing session (7.28).

Table 6
Means, Standard Deviations and Analysis of Variance for Number of Responses per Minute

Testing Condition and Testing Session	Mean	S.D.
Time-Limit Condition (N=15)		
Both sessions combined	8.93	1.98
Session 1	8.19	1.42
Session 2	9.66	2.18
No-Time-Limit Condition (N=15)		
Both sessions combined	6.60	1.88
Session 1	6.36	1.44
Session 2	6.84	2.21
Testing Session (Conditions Combined)		
Session 1	7.28	1.70
Session 2	8.25	2.62

Analysis of Variance

Source of Variation	df	MF	F	p
Between Subjects				
Testing condition	1	81.11	13.20	.001
Subjects within groups	28	6.14		
Within Subjects				
Testing session	1	14.09	19.60	.001
Testing condition x testing session	1	4.65	5.08	.031
Testing session x subjects within groups	28	.72		

The data also show that in moving from the first to the second testing session, the rate of response for the time-limit condition increased more than the rate of response for the no-time-limit condition, since there was a significant ($p<.05$) interaction between testing condition and testing session. Figure 6 shows the pattern of this interaction.

Under the time-limit condition the correlation between Session 1 and 2 response rates was .87. Under the no-time-limit condition the correlation between Session 1 and 2 response rates was .86.

Response accuracy. Table 7 shows the group means and standard deviations for response accuracy under the time-limit and no-time-limit conditions. Also shown are the results of the repeated measurements analysis

Figure 6
Group Means for the Number of Responses per Minute
by Testing Condition and Testing Session

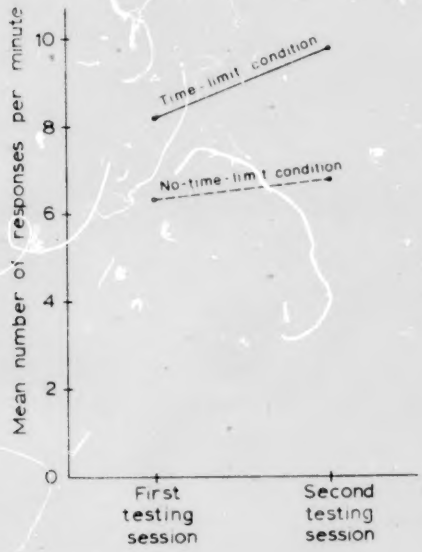


Table 7
Means, Standard Deviations and Analysis of Variance
for Proportion of Items Answered Correctly

Testing Condition and Testing Session	Mean	S.D.
Time-Limit Condition (N=15)		
Both sessions combined	.58	.13
Session 1	.57	.13
Session 2	.58	.13
No-Time-Limit Condition (N=15)		
Both sessions combined	.56	.18
Session 1	.56	.18
Session 2	.56	.18
Testing Session (Conditions Combined)		
Session 1	.56	.16
Session 2	.57	.16

Analysis of Variance

Source of Variation	df	MF	F	p
Between Subjects				
Testing condition	1	.0040	.09	.770
Subjects within groups	28	.0470		
Within Subjects				
Testing session	1	.0005	.36	.556
Testing condition x testing session	1	.0005	.36	.556
Testing session x subjects, within groups	28	.0013		

of variance. There were no significant main effects or interactions. Under the time-limit condition the correlation between Session 1 and 2 response accuracies was .96. Under the no-time-limit condition the correlation between Session 1 and 2 response accuracies was .94. Under the time-limit condition the correlations between response rate and response accuracy were -.16 and -.07 for Sessions 1 and 2, respectively. Under the no-time-limit condition the correlations between response rate and response accuracy were .03 and -.11 for Sessions 1 and 2, respectively. None of these last four correlations was significantly different from zero.

Table 8
Means, Standard Deviations and Analysis of Variance for Variability of Item Response Latencies

Testing Condition and Testing Session	Mean	S.D.
Time-Limit Condition (N=15)		
Both sessions combined	3.59	1.19
Session 1	3.91	1.25
Session 2	3.27	1.04
No-Time-Limit Condition (N=15)		
Both sessions combined	5.52	2.20
Session 1	5.36	1.97
Session 2	5.68	2.39
Testing Session (Conditions Combined)		
Session 1	4.64	1.80
Session 2	4.48	2.20

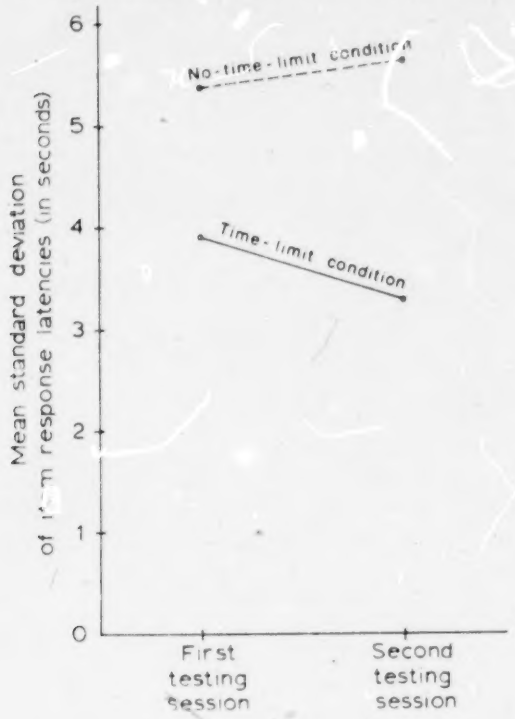
Analysis of Variance

Source of Variance	df	MS	F	p
Between Subjects				
Testing condition	1	56.07	10.63	.003
Subjects within groups	28	5.28		
Within Subjects				
Testing session	1	.38	.46	.510
Testing condition x testing session	1	3.46	4.14	.049
Testing session x subjects, within groups	28	.83		

Item response latencies. Table 8 shows the group means and standard deviations for the variability of item response latencies under the time-limit and no-time-limit conditions for the two testing sessions. Also shown are the results of the repeated measurements analysis of variance for that variable. The average variability of item response latencies was significantly smaller (p<.01) under the time-limit condition (3.59) than under the no-time-limit condition (5.52). There was no main effect for testing sessions, but there was a significant interaction between testing conditions and testing sessions (p<.05). Figure 7 shows

the pattern of this interaction. Under the time-limit condition the variability of item response latencies decreased when moving from the first to the second testing session. Under the no-time-limit condition the variability of item response latencies increased when moving from the first to the second testing session.

Figure 7
Group Means for the Variability of Item Response Latencies by Testing Condition and Testing Session



Conclusions. The results of Study 3 were consistent with the results of the two previous studies. Higher response rates were observed under the time-limit condition than under the no-time-limit condition, while response accuracy remained consistent across testing conditions. The analysis of response latency data implies that testees may learn different test-taking strategies in responding to time-limit versus no-time-limit conditions.

Summary and Implications

Summary

Although there are wide individual differences in response rates and response accuracies under both time-limit and no-time-limit conditions, the results of the three studies may be summarized as follows:

1. As expected, given the apparent differences between the testing conditions, time-limit response rates were higher than no-time-limit response rates.

2. Response accuracy was consistent across time-limit and no-time-limit conditions. Individuals can change their response rates without affecting their accuracy.

3. Most individuals showed increases in response rate during the course of a time-limit testing session, whereas consistent response rates were typical of no-time-limit testing sessions.

4. When the same persons received both time-limit and no-time-limit conditions, there were high positive correlations between time-limit response rates and no-time-limit response rates.

5. There were high positive correlations between time-limit and no-time-limit response accuracies under the two experimental conditions.

6. Under both time-limit and no-time-limit conditions, correlations between response rates and response accuracies were effectively zero. The only indication of a relationship between response rate and response accuracy was in the first study, when testees obtaining high scores on a no-time-limit pretest tended to have higher response rates under both time-limit and no-time-limit conditions.

7. There was a correlation between item difficulty and item response latency: individuals take more time in responding to the more difficult items. Under a time-limit condition, however, individuals take proportionately less time in responding to the more difficult items.

8. Also reflecting the relationship between item difficulty and response latency, response latencies for incorrectly answered items were longer than response latencies for correctly answered items. But the differences between the mean latencies for correct and incorrect responses were less under a time-limit condition.

9. When two short testing sessions were given in succession under the same administrative conditions, the mean response rate during the second session was higher than the mean rate during the first session. This was especially true when tests were administered under a time-limit condition.

10. When two short time-limit testing sessions were given in succession, the variability in item response latencies decreased when moving from the first to the second testing

session. But when two short no-time-limit testing sessions were given in succession, the variability in item response latencies increased when moving from the first to the second testing session.

The three studies showed similar results with regard to response accuracy. Given an item arrangement that ensures consistent average item difficulty throughout the test, there were no significant differences in response accuracy for time-limit versus no-time-limit conditions. Thus it might appear that response accuracy, or proportion of items answered correctly, is an adequate index of ability level under both time-limit and no-time-limit modes of administration. However, considered in relation to the findings on response latencies and item difficulties in both Study 1 and Study 2, this interpretation is suspect under time-limit conditions of administration. These two studies showed that under time-limit conditions of administration, students spent proportionately less time on items of higher difficulty or on items answered incorrectly. Since accuracy scores were not affected by the imposition of time limits, these data imply a test-taking strategy designed to maximize the number of correct responses. To implement this strategy, students apparently guess quickly on difficult-appearing items rather than spend time trying to determine the correct answer. By using this strategy they are able to maintain the same accuracy levels while increasing their response rates.

Consequently, if a "maximum performance" conception of ability level is adopted, scores from time-limit tests might not yield accurate indications of the highest level of item difficulty that a given testee is able to answer correctly. This would result from the fact that testees under time-limit conditions would not spend sufficient time attempting to solve difficult items, which they might be capable of solving, in an attempt to maximize the number of items answered correctly. This is less likely to occur under no-time-limit conditions, where testees appear to deliberate more on their responses to difficult items. Thus, under no-time-limit conditions they are more likely to obtain the correct answer on the more difficult items and to exhibit the maximum level of performance of which they are capable.

Unlike response accuracies, individual response rates were not consistent across different testing conditions or across different testing sessions. Higher response rates were observed under time-limit conditions than under no-time-limit conditions. This could be due to the different test-taking strategies used by the students.

The test response records obtained in Study 1 indicate that there is intra-individual variability in response rates within a single testing session. This intra-individual variability can be interpreted as different modes of adaptation to time-limit or no-time-limit testing. The response rates for most individuals in Study 2 varied when moving from a time-limit to a no-time-limit condition or from a no-time-limit to a time-limit condition. Given these results, it is interesting to note that in Study 2 response rates under a time-limit condition correlated

highly with response rates under a no-time-limit condition. Although individuals may change their response rate under different testing conditions, they do so in predictable ways. Response accuracies also were generally predictable between testing conditions, with slightly lower correlations when no-time-limit tests were administered first. Both Studies 2 and 3 showed that there was essentially a zero correlation between response rate and response accuracy.

Implications

The results of these studies have no direct bearing on whether time-limit or no-time-limit testing procedures provide better measurement. However, the results do have some implications for the utility of scores derived from time-limit tests. The typical time-limit test score is the number of items that are answered correctly within the time limit. All other things being equal, time-limit test scores will be higher for testees who work faster. But testees who adopt the test-taking strategy illustrated by the results of these studies will obtain higher number-correct scores than others, working equally fast, who do not adopt that strategy. The strategy, as shown by the data of Studies 1 and 2, involves spending proportionately less time on difficult test items, permitting the testee to encounter and answer correctly more easy items.

Thus, number-correct scores on time-limit tests include at least four components: 1) overall response accuracy; 2) overall response rate; 3) an intra-individual component due to test-taking strategy; and 4) an intra-individual component due to test-taking style, or mode of adaptation. The first two of these components are uncorrelated. The relative contribution of the other two to time-limit scores is unknown at present. The conglomeration of these variables into a single test score is likely to reduce its relationship with actual ability. On the other hand, number correct scores on no-time-limit tests are more likely to be a function solely of response accuracy.

The results of Study 3 provide further evidence of problems in the use of number correct scores in time-limit tests. Given two equivalent item pools administered under identical instructions, testees were able to increase their response rates considerably when moving from one testing session to the next. These results indicate that response rate, rather than being completely determined by stable personality variables, and rather than being just another indication of ability level, is a test-taking style or strategy that is amenable to learning or practice effects.

Despite all that is known about time-limit and no-time-limit test scores, about their relationships to one another, and about their reliability and validity, surprisingly little is known about the behavior that yields test scores. Test scores are a function of test-taking behavior. Progress in improving the reliability and validity

of ability test scores could result from further studies that take an experimental approach to psychometrics. Further study is needed into the areas of test-taking styles, test-taking strategies, and test-taking behaviors. Computer administration of ability test items makes it possible to implement an experimental approach to understanding the determinants of ability test responses.

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1 U.S. Civil Service Commission
Federal Office Building
Chicago Regional Staff Division
Regional Psychologist
230 South Dearborn Street
Chicago, IL 60604
ATTN: C. S. Winiewicz

1 Dr. Carl Frederiksen
Learning Division, Basic Skills Group
National Institute of Education
1200 19th Street, N.W.
Washington, DC 20208

Miscellaneous

1 Dr. Scarvia B. Anderson
Educational Testing Service
17 Executive Park Drive, N.E.
Atlanta, GA 30329

1 Dr. John Annett
Department of Psychology
The University of Warwick
Coventry CV47AL
ENGLAND

1 Dr. Gerald V. Barrett
University of Akron
Department of Psychology
Akron, OH 44325

1 Dr. Bernard M. Bass
University of Rochester
Graduate School of Management
Rochester, NY 14627

1 Century Research Corporation
4113 Lee Highway
Arlington, VA 22207

1 Dr. Kenneth E. Clark
University of Rochester
College of Arts and Sciences
River Campus Station
Rochester, NY 14627

1 Dr. Norman Cliff
University of Southern California
Department of Psychology
University Park
Los Angeles, CA 90007

1 Dr. Allan M. Collins
Bolt Beranek and Newman, Inc.
50 Moulton Street
Cambridge, MA 02138

1 Dr. Rene' V. Dawis
University of Minnesota
Department of Psychology
Minneapolis, MN 55455

1 Dr. Ruth Day
Yale University
Department of Psychology
2 Hillhouse Avenue
New Haven, CT 06520

1 Dr. Norman R. Dixon
200 South Craig Street
University of Pittsburgh
Pittsburgh, PA 15260

1 Dr. Marvin D. Dunnette
University of Minnesota
Department of Psychology
Minneapolis, MN 55455

1 ERIC
Processing and Reference Facility
4833 Rugby Avenue
Bethesda, MD 20014

1 Dr. Victor Fields
Montgomery College
Department of Psychology
Rockville, MD 20850

1 Dr. Edwin A. Fleishman
Visiting Professor
University of California
Graduate School of Administration
Irvine, CA 92664

1 Dr. Robert Glaser, Co-Director
University of Pittsburgh
3939 O'Hara Street
Pittsburgh, PA 15213

1 Mr. Harry H. Harman
Educational Testing Service
Princeton, NJ 08540

1 Dr. Richard S. Hatch
Decision Systems Associates, Inc.
5640 Nicholson Lane
Rockville, MD 20852

1 Dr. M. D. Havron
Human Sciences Research, Inc.
7710 Old Spring House Road
West Gate Industrial Park
McLean, VA 22101

1 HumRRO Central Division
400 Plaza Building
Pace Boulevard at Fairfield Drive
Pensacola, FL 32505

1 HumRRO/Western Division
27857 Berwick Drive
Carmel, CA 93921
ATTN: Library

1 HumRRO Central Division/Columbus Office
Suite 23, 2601 Cross Country Drive
Columbus, GA 31906

1 HumRRO
Joseph A. Austin Building
1939 Goldsmith Lane
Louisville, KY 40218

1 Dr. Lawrence B. Johnson
Lawrence Johnson & Associates, Inc.
2001 S Street, N.W., Suite 502
Washington, DC 20009

1 Dr. Roger A. Kaufman
203 Dodd Hall
Florida State University
Tallahassee, FL 32306

1 Dr. David Klahr
Carnegie-Mellon University
Department of Psychology
Pittsburgh, PA 15213

1 Dr. Frederick M. Lord
Educational Testing Service
Princeton, NJ 08540

1 Dr. Robert R. Mackie
Human Factors Research, Inc.
6780 Corton Drive
Santa Barbara Research Park
Goleta, CA 93017

1 Dr. William C. Mann
University of Southern California
Information Sciences Institute
4676 Admiralty Way
Marina Del Rey, CA 90291

1 Mr. Edmond Marks
315 Old Main
Pennsylvania State University
University Park, PA 16802

1 Dr. Leo Munday, Vice President
American College Testing Program
P.O. Box 168
Iowa City, IA 52240

1 Dr. Donald A. Norman
University of California, San Diego
Department of Psychology
LaJolla, CA 92037

1 Mr. A. J. Pesch, President
Eclectech Associates, Inc.
P.O. Box 178
North Stonington, CT 06359

1 Dr. Diane M. Ramsey-Klee
R-K Research & System Design
3947 Ridgemont Drive
Malibu, CA 90265

1 Dr. Joseph W. Rigney
University of Southern California
Behavioral Technology Laboratories
3717 South Grand
Los Angeles, CA 90007

1 Dr. George E. Rowland
Rowland and Company, Inc.
P.O. Box 61
Haddonfield, NJ 08033

1 Dr. Benjamin Schneider
University of Maryland
Department of Psychology
College Park, MD 20742

1 Dr. Arthur I. Siegel
Applied Psychological Services
404 East Lancaster Avenue
Wayne, PA 19087

1 Dr. Henry P. Sims, Jr.
Room 630 - Business
Indiana University
Bloomington, IN 47401

1 Dr. Richard Snow
Stanford University
School of Education
Stanford, CA 94305

1 Mr. George Wheaton
American Institutes for Research
3301 New Mexico Avenue, N.W.
Washington, DC 20016

1 Dr. K. Wescourt
Stanford University
Institute for Mathematical Studies
in the Social Sciences
Stanford CA 94305

1 Richard T. Mowday
College of Business Administration
University of Nebraska, Lincoln
Lincoln, NE 68588

1 Dr. John J. Collins
Vice President
Essex Corporation
6305 Caminito Estrellado
San Diego, CA 92120

1 Dr. Lyle Schoenfeldt
Department of Psychology
University of Georgia
Athens, Georgia 30602

1 Dr. Patrick Suppes, Director
Institute for Mathematical Studies
in the Social Sciences
Stanford University
Stanford, CA 94305